A Collapse Analysis Code and Its Recent Applications

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ABSTRACT

Catastrophic disasters of large-scale framed structures occurred recently are mainly caused by sudden, extreme external loads such as aircraft collision, explosion, large seismic excitation, and big fire. Dynamic codes are generally used to investigate such phenomena. However, strong nonlinearity in the deformation of structures and rapidness of the external loads often generate higher hurdle in the analyses. The authors have developed an adaptive finite element code with the use of an ASI (Adaptively Shifted Integration)-Gauss technique [1], which provides higher computational efficiency than the conventional code in such analyses, and enable us to cope with dynamic behavior with strong nonlinearities including phenomena such as member fracture and elemental contact. Contact release and re-contact algorithms are also developed and implemented in the code to realize complex behaviors of structural members during impact and collapse sequence.

The code has been applied to various collapse analyses of buildings. One of the various collapse simulations is a fire-induced collapse analysis of a high-rise tower [2], which is carried out for an investigation seeking for the true cause of the total collapse of New York World Trade Center (WTC) towers, which collapsed in 2001.

A demolition planning tool based on a parameter called the key element index [3], which indicates the contribution of a structural column to the vertical capacity of the structure, is also developed by using the code. Two ways of selecting specific columns to demolish the whole structure are demonstrated: selecting the columns from the largest index value and from the smallest index value. The demolition results are confirmed numerically by carrying out some collapse analyses, and the tendencies of the demolition modes to follow the key element index values are estimated. The numerical results suggest that for a successful demolition, a group of columns with the largest key element index values should be selected when explosives are ignited in a simultaneous blast, whereas those with the smallest values should be selected when explosives are ignited sequentially, with a final blast set on a column with a large index value.

A seismic pounding analysis is also performed on a simulated model of the Nuevo Leon buildings, in which two out of the three collapsed completely in the 1985 Mexican earthquake, to understand the impact and collapse behavior of structures built near each other [4]. The difference of natural periods between the buildings, which was caused by the damages from previous earthquakes, may have triggered the collision between the north and the center buildings. This collision eventually led to the collapse of the center building, followed by the destruction of the north building.

Some other recent applications of the numerical code are also demonstrated in the presentation.

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